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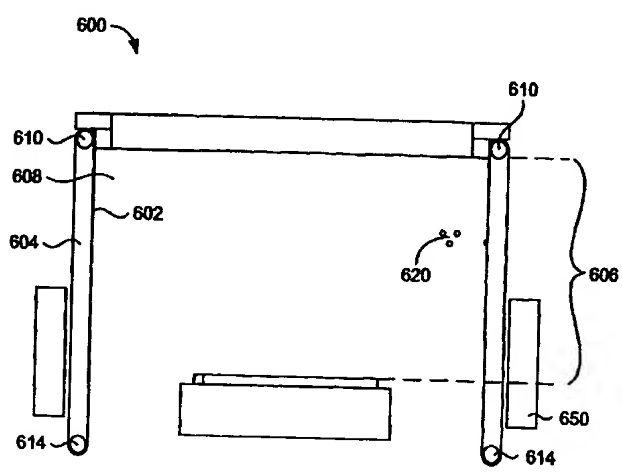
(54) Title: METHOD AND APPARATUS FOR CONTROLLING CHAMBER SURFACES IN A SEMICONDUCTOR PROCESSING REACTOR




(57) Abstract: A system for processing a substrate using a process gas is disclosed. The system forming volatile and non-volatile species during processing. The system includes a process chamber within which the processing is performed. The process chamber being configured to enclose the substrate, and having a chamber surface proximate to the substrate. The system further includes a chamber surface protection arrangement configured for shielding the surface from the non-volatile species formed during processing. The chamber surface protection arrangement includes an adsorbing film that is disposed inside the process chamber and substantially adjacent to the chamber surface. The adsorbing film being configured to prevent the non-volatile species from contacting the chamber surface, and arranged to adsorb a substantial portion of the non-volatile species that contact the adsorbing film. The adsorbing film further being arranged for removing the adsorbed non-volatile species from the process chamber.

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# METHOD AND APPARATUS FOR CONTROLLING CHAMBER SURFACES IN A SEMICONDUCTOR PROCESSING REACTOR

## Background of the Invention

The present invention relates to the fabrication of semiconductor integrated circuits (IC's). More particularly, the present invention relates to methods and apparatuses for controlling the amount of deposits that accumulate on chamber surfaces.

During the manufacture of a semiconductor-based product, for example, a flat panel display or an integrated circuit, multiple deposition and/or etching steps may be employed inside a process chamber. During the deposition step, materials are deposited onto a substrate surface (such as, but not limited to, the surface of a glass panel or a wafer). Conversely, etching may be employed to selectively remove materials from predefined areas on the substrate surface.

One particular method of processing uses an inductive source to generate a plasma. Fig. 1 illustrates a prior art inductive plasma processing reactor 100 that is used for processing a substrate. A typical inductive plasma processing reactor includes a chamber 102 with an antenna or inductive coil 104 disposed above a dielectric window 106. Typically, antenna 104 is operatively coupled to a first RF power source 108. Furthermore, a gas port 110 is provided within chamber 102 that is arranged for releasing gaseous source materials, e.g., the etchant source gases, into the RF-induced plasma region between dielectric window 106 and a substrate 112. Substrate 112 is introduced into chamber 102 and disposed on a chuck 114, which generally acts as a bottom electrode and is operatively coupled to a second RF power source 116. Additionally, an exhaust port 120 is typically provided with process chamber 102 for exhausting by-product gases formed during processing. In most instances, exhaust port 120 is coupled to a pump (not shown) that maintains the appropriate pressure inside chamber 102.

In order to create a plasma, a process gas is input into chamber 102 through gas port 110. Power is then supplied to inductive coil 104 using first RF power source 108, and a large electric field is produced inside chamber 102. Correspondingly, the electric field ionizes a portion of the process gas. As a result, ions, electrons and neutral gas molecules (and/or atoms) are contained inside the plasma 118.

Once the plasma has been formed, neutral gas molecules inside the plasma are directed towards the surface of the substrate by diffusion, i.e., the random movement of molecules inside the chamber. In this manner, a layer of neutral species (e.g., neutral gas molecules) is typically formed along the surface of substrate 112. Correspondingly, when bottom electrode 114 is powered, ions tend to accelerate towards the substrate where they, in combination with neutral species, activate the reaction, e.g., etching or deposition.

Because of the nature of the etching and deposition processes, the chamber surfaces inside the process chamber can be adversely effected. For example, both processes may leave deposits on the walls of the process chamber. The deposits may accumulate on the walls and become the source of harmful particulate, especially when the deposits flake off onto the substrate surface. Particulate contamination may produce undesirable and/or unpredictable results. For example, particles on the substrate surface may block a portion of the substrate that needs to be etched. In this manner, device failure may increase and therefore cause a reduction in productivity. Furthermore, accumulation of material on the chamber wall may cause process drift, and even process failure.

In the past, cleaning has been required to remove the deposited material from the surfaces of the process chamber. In wet cleaning, the soiled parts of the process chamber that have deposits are removed from the chamber, and dipped (or immersed) in various fluids, which are configured to remove the deposits and therefore clean the parts, i.e., chemicals that attack the deposits. In dry cleaning, a gaseous cleaning agent or reactant is introduced into the process chamber, wherein the reactants chemically react with and vaporize the deposits on the chamber surfaces. The vaporized deposits (volatile) are then pumped out of the chamber.

However, both cases typically result in a loss of productivity, i.e., lower substrate throughput. In wet cleaning, the processing machine has to be shut down, and the parts have to be manually removed. In dry cleaning, substrate processing is stopped in order to input the cleaning gas, and export the removed material. Also, cleaning in general, may only be marginally successful. That is, not all of the deposits will be removed. Furthermore, neither cleaning method addresses the problem of process variation that occurs during repeated processing because of surface changes. Alternating deposition and cleaning of the chamber surface may, for example, change the recombination rate of ionized reactant gas, or the electrical impedance to ground of that surface resulting in process variation.

Current strategies for addressing deposition on chamber surfaces have been directed at heating the chamber surfaces to either reduce the accumulation of deposits or aid in the removal of deposits on the chamber surface. Typically, this is accomplished by placing a temperature controlled ceramic liner adjacent to the process chamber surfaces. Generally speaking, materials become more volatile at higher temperatures (e.g., reach boiling point) and therefore, by increasing the temperature of the liner, some of the non-volatile deposits tend to be transformed into volatile species that can be evacuated from the chamber. However, a substantial amount of deposits tend not stick to the chamber surfaces.

Additionally, because the chamber walls are at high temperatures, they are hard to vacuum seal, and difficult to engineer. For example, heating the chamber walls creates thermal expansion, which changes the dimensions of the chamber wall. Furthermore, the change in dimensions, especially over time, tend to fatigue parts. Additionally, heating the chamber walls may have some adverse process effects.

In view of the foregoing, there are desired improved techniques for controlling the amount of deposits that accumulate on chamber surfaces.

## Summary of the Invention

The invention relates, in one embodiment, to a system for processing a substrate using a process gas. The system forming volatile and non-volatile species during processing. The system includes a process chamber within which the processing is performed. The process chamber being configured to enclose the substrate, and having a chamber surface proximate to the substrate. The system further includes a chamber surface protection arrangement configured for shielding the surface from the non-volatile species formed during processing. The chamber surface protection arrangement includes an adsorbing film that is disposed inside the process chamber and substantially adjacent to the chamber surface. The adsorbing film being configured to prevent the non-volatile species from contacting the chamber surface, and arranged to adsorb a substantial portion of the non-volatile species that contact the adsorbing film. The adsorbing film further being arranged for removing the adsorbed non-volatile species from the process chamber, the adsorbing film being one of a fluid adsorbing film or a flexible adsorbing film.

The invention relates, in another embodiment, to a reaction chamber for processing a substrate. The reaction chamber includes a process chamber having an active region within

which the processing is performed on the substrate. The reaction chamber further includes a moving film disposed inside the process chamber. The moving film defining a portion of the inner periphery of the process chamber, and configured for refreshing itself by moving in and out of the active region.

The invention relates, in another embodiment, to a method for controlling the amount of deposits that accumulate along surfaces in a process chamber during processing of a substrate. The method includes introducing a moving film inside an active area of the process chamber. The method further includes collecting a plurality of non-volatile species on the moving film. The method also includes removing the moving film from the active area of the process chamber.

The invention relates, in another embodiment, to a particle collector for controlling the accumulation of deposits along surfaces inside a process chamber of a semiconductor processing reactor used for processing a substrate. The particle collector includes a process chamber having a first end and a second end. The process chamber being defined and enclosed by a chamber wall. The particle collector further includes a fluid configured for flowing on the chamber wall. The fluid being configured to collect a plurality of non-volatile species formed during processing when the fluid flows past the chamber wall. The particle collector also includes a dispenser for dispensing the fluid at the first end of the process chamber. The particle collector additionally includes a collector for collecting the fluid and the collected non-volatile species at the second end of the process chamber. The particle collector further includes a pump for pumping the fluid to the dispenser.

## Brief Description of the Drawings

The present invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:

Fig. 1 illustrates a prior art inductive plasma processing reactor that is used for processing a substrate.

Fig. 2 illustrates a simplified schematic of a typical inductively coupled plasma reactor, along with a particle collector arrangement that includes a moving surface, according to one embodiment of the present invention.

Fig. 3 shows a broken away side view of the particle collector arrangement that

includes a moving surface, according to one embodiment of the present invention.

Fig. 4 illustrates a simplified schematic of a typical inductively coupled plasma reactor, along with a particle collector arrangement that includes a fluid moving surface, according to one embodiment of the present invention.

Fig. 5 shows a broken away side view of the particle collector arrangement that includes a fluid moving surface, according to one embodiment of the present invention.

Fig. 6 illustrates a simplified schematic of a typical inductively coupled plasma reactor, along with a particle collector arrangement that includes a flexible moving surface, according to one embodiment of the present invention.

Fig. 7 shows a broken away side view of the particle collector arrangement that includes a flexible moving surface, according to one embodiment of the present invention.

Fig. 8 illustrates a top view of a processing system, which includes a particle collector arrangement that utilizes a flexible moving surface, according to one embodiment of the present invention.

## Detailed Description of Preferred Embodiments

The present invention will now be described in detail with reference to a few preferred embodiments thereof and as illustrated in the accompanying drawings. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be obvious, however, to one skilled in the art, that the present invention may be practiced without some or all of these specific details. In other instances, well known process steps have not been described in detail in order not to unnecessarily obscure the present invention.

In accordance with one aspect of the present invention, deposits along chamber surfaces are substantially reduced by disposing a moving film inside a process chamber. The moving film is arranged to control the amount of deposits that typically accumulate along the surfaces of a process chamber by collecting and removing particles that tend to form deposits inside the process chamber. Preferably, the particles are collected in an active region of the process chamber so that a substantial amount of deposit forming particles are collected by the moving film. Furthermore, when a predetermined amount of particles have been collected by the moving film, the moving film is configured to refresh itself by moving the collected particles out of the active area, and moving a fresh moving film into the active area.

Correspondingly, the accumulation of particles that typically deposit on the chamber surfaces can be controlled, and therefore reduced. Accordingly, by controlling and reducing the accumulation of deposits on the chamber surfaces, the amount of particle contamination inside the chamber may be reduced, the process shift and drift associated with changes in the chamber surfaces may be minimized and the need for wet or dry cleaning may be eliminated.

In accordance with another aspect of the present invention, a cleaning system is provided to regenerate the moving film. The cleaning arrangement is arranged to remove the collected particles from the moving film in a non-active region of the processing system. Correspondingly, after the collected particles are removed from the moving film, the moving film may be reused and introduced into the active area. By reusing the moving film, costs associated with waste removal and new moving films are substantially eliminated.

It is contemplated that the present invention may be used in any reactor that is suitable for etching or deposition.. By way of example, the present invention may be used in any of a number of suitable and known deposition processes, including chemical vapor deposition (CVD), plasma enhanced chemical vapor deposition (PECVD), and physical vapor deposition (PVD), such as sputtering. Furthermore, the present invention may be used in any of a number of suitable and known etching processes, including those adapted for dry etching, plasma etching, reactive ion etching (RIE), magnetically enhanced reactive ion etching (MERIE), electron cyclotron resonance (ECR), or the like.

Further still, it is contemplated that the invention may be practiced in any of the above reactors, as well as other suitable plasma processing reactors. Note that the above is true irrespective of whether energy to the plasma is delivered through capacitively coupled parallel electrode plates, through ECR microwave plasma sources, or through inductively coupled RF sources such as helicon, helical resonators, and RF antenna (planar or non planar). ECR and inductively coupled processing systems, among others, are readily available commercially. Inductively coupled plasma processing systems are available from, for example, Lam Research Corporation of Fremont, California.

In a preferred embodiment, the present invention is practiced in a high density plasma reactor, such as any one of the inductively coupled plasma reactors, which are available from Lam Research Corporation of Fremont, CA. Fig. 2 illustrates a simplified schematic of a typical inductively coupled plasma reactor 200. Plasma reactor 200 includes a substantially cylindrical process chamber 202 within which a plasma 204 is both ignited and sustained for

processing a substrate 206. Substrate 206 represents the work-piece to be processed, which may represent, for example, a semiconductor substrate to be etched, deposited, or otherwise processed or a glass panel to be processed into a flat panel display. Additionally, process chamber 202 is configured with a substantially vertical chamber wall 203 that may be formed from a variety of materials such as anodized aluminum.

Plasma processing system 200 further includes an inductive coil or antenna 210 (represented by a coil) and a coupling window 212, which are configured to couple power to plasma 204. Antenna 210 is powered by a first RF power source 214 via a matching network (not shown in Fig. 2 to simplify the illustration). Coupling window 212 is configured to allow the passage of the first RF energy from antenna arrangement 210 to the interior of process chamber 202. Preferably, coupling window 212 is disposed between substrate 206 and antenna arrangement 210.

A gas injector 215 is typically provided within chamber 202. Gas injector 215 is preferably disposed around the inner periphery of chamber 202 and is arranged for releasing gaseous source materials, e.g., the etchant source gases, into the RF-induced plasma region between coupling window 212 and substrate 206. Alternatively, the gaseous source materials may also be released from ports built into the walls of the chamber itself or through a shower head arranged in the coupling window.

For the most part, substrate 206 is introduced into chamber 202 and disposed on a chuck 216, which is configured to hold the substrate during processing. Chuck 216 may represent, for example, an ESC (electrostatic) chuck, which secures substrate 206 to the chuck's surface by electrostatic force. Typically, chuck 216 acts as a bottom electrode and is preferably biased by a second RF power source 218 (also typically via a matching network). Chuck 216 may also be configured to move between a first position (not shown) for loading and unloading substrate 206 and a second position (not shown) for processing the substrate.

Still referring to Fig. 2, an exhaust port 220 is disposed between chamber wall 203 and chuck 216. Preferably, exhaust port 220 is configured for exhausting by-product (e.g. volatile) gases formed during processing. Further, exhaust port 220 is coupled to a turbomolecular pump (not shown), typically located outside of chamber 202. As is well known to those skilled in the art, the turbomolecular pump is throttled to maintain the appropriate pressure inside chamber 202.

In order to create a plasma, a process gas is input into chamber 202 through gas injector 215. Power is then supplied to antenna arrangement 210 using first RF power source 214, and a large electric field is induced inside chamber 202 through coupling window 212. Correspondingly, the electric field ionizes a portion of the process gas. As a result, ions, electrons and neutral gas molecules (and/or atoms) are contained inside the plasma 204.

During both etching and deposition, materials may be deposited on the surfaces of the plasma processing chamber. For example, the etch by-products formed during etching and the material to be deposited during deposition may form deposits on the plasma processing chamber. By way of example, some materials that typically remain non-volatile throughout processing are silicon oxyhalides, platinum (Pt), copper (Cu), ferro-electric materials, and high K materials. As is well known to those skilled in the art, volatile species may be pumped out of the process chamber and therefore do not have the same adverse effect as the non-volatile species.

Figs. 2 & 3 illustrate, in accordance with one embodiment of the present invention, a particle collector arrangement 250, which is configured for collecting and removing non-volatile species formed during processing (e.g., deposition or etching) from the process chamber. Particle collector arrangement 250 includes a moving surface 252 that is disposed inside process chamber 202. Moving surface 252 is configured to define a portion of the inner periphery of process chamber 202, and therefore is exposed to the processing environment. Furthermore, moving surface 252 is preferably arranged to line at least a portion of the inner peripheral surface of chamber wall 203. However, it should be understood that this is not a limitation and that the actual placement of the moving surface may vary according to the specific needs of each plasma processing system. By way of example, a gap may be provided between the moving surface and the chamber wall.

Further, a portion of moving surface 252 is preferably disposed in an active region 254 of process chamber 202. Active region 254 is defined by an upper process area 256 and a lower process area 258, which generally correspond to coupling window 212 and substrate 206. In most instances, active region 254 is the area where the plasma cloud is contained, for example, for etching, deposition and the like. Correspondingly, a plurality of non volatile species 260 and a plurality of volatile species 262 are typically present inside active area 254.

Moving surface 252 is preferably configured to collect non-volatile species 260 that are disposed in active region 254 proximate to moving surface 252. That is, the moving

surface provides a surface for non-volatile species to be adsorbed. Preferably, when non-volatile species 260 come into contact with moving surface 252, they stick (adsorbed) to moving surface 252, forming collected non-volatile species 264. Correspondingly, moving surface 252 prevents non-volatile species 260 from adhering to chamber wall 203, and therefore protects chamber wall 203 from unwanted deposits. It should be understood that the collecting of non-volatile species is not limited to the active region and that collecting may occur in non active areas as well, for example, collecting may occur in the exhaust port below the substrate. Accordingly, by collecting the non-volatile species, the non-volatile species that would typically contaminate the pumping arrangement are eliminated. Additionally, moving surface 252 is preferably configured to be chemically inert to the reactive species used to process the substrate.

Moreover, moving surface 252 is preferably configured to move inside process chamber 202. More preferably, moving surface 252 is configured to move in and out of active area 254. Correspondingly, when a predetermined amount of collected non-volatile species 264 (e.g., deposits) have been collected on moving surface 252, moving surface 252 refreshes itself by moving the saturated portion of moving surface 252 out of active region 254, and by moving an unsaturated portion of moving surface 252 into active region 254. In this manner, the build up of deposits inside chamber 202 is substantially reduced.

More specifically, collected non-volatile species 264 are collected in active region 254 and transported to a non active region, which is typically located away from active region 254. By way of example, the non active region may be arranged to be below lower process area 258 or entirely outside the process chamber. Regardless of the location of the non-active region, the collected non volatile species 264 are removed from active region 254 and thus cannot accumulate and form deposits, which may lead to particle contamination and/or process drift.

Furthermore, the moving surface is arranged to move at predetermined times during processing. The predetermined times are preferably configured to maintain a substantially clean moving surface by moving the moving surface out of the active area when a predetermined amount of deposits is collected on the moving surface. For the most part, the predetermined times tend to vary according the type of processing (e.g., etching or deposition) and the specific process conditions. Accordingly, by moving the moving surface at predetermined times, the accumulation of deposits may be controlled so that particle

contamination does not occur and process variation due to a changing surface is minimized.

Moreover, the moving surface is preferably moved without altering the process conditions such as chamber pressure, process gas flow, gas chemistry and the like. That is, the processing conditions are preferably allowed to remain unchanged when the moving surface is moving in the active region to collect non-volatile species, remove non-volatile species and introduce a clean moving surface. By not changing the process conditions, i.e., pumping up, pumping down, inputting a first gas, exporting a second gas, etc., the substrate throughput can be increased.

In one embodiment, the moving surface is configured to move continuously during processing. For example, the moving surface moves during all of the processing steps, i.e., inserting a substrate into the chamber, inputting a process gas, creating the plasma, processing the substrate, removing the substrate, etc., and throughout a plurality of substrate cycles. By continuously moving the moving surface, the chamber surfaces are continuously refreshed, and thus the accumulation of deposits are substantially eliminated from the surfaces inside the process chamber.

The amount of deposits collected before moving the moving surface is chiefly governed by the amount of accumulation formed during processing and the velocity of the moving surface. Therefore, in this embodiment, the velocity of the moving surface is preferably balanced with the amount of particles being deposited to maintain a fresh surface inside the active area.

In another embodiment, the moving surface is moved periodically during processing. More specifically, the moving surface is allowed to prolong for a sufficient amount of time to allow deposits to form on the moving surface. That is, the moving surface moves when a predetermined amount of deposits are formed on the moving surface. For example, the moving surface moves prior to (or subsequent to) a specific processing step such as inserting a substrate into the process chamber. In one specific example, the moving surface is inserted into the process chamber, the substrate is processed, the non-volatile species are collected, the substrate is removed from the chamber and then the moving surface is moved out of the chamber. In another specific example, the moving surface is inserted into the process chamber, five substrates are individually processed, the non-volatile species are collected for five substrates, after the last substrate (e.g., fifth) is removed from the chamber, then the moving surface is moved out of the chamber. It should be noted that the number of refreshing

cycles are for exemplary purposes only and that the present invention is not limited by only one or five substrates and that any number of substrates may be processed before the moving surface is refreshed.

However, it is preferable to keep the number small so that excessive deposits tend not be formed on the moving surface. An appropriate balance between the amount of deposits and the refreshing cycle should be determined so that the accumulation of deposits is minimized.

To further discuss the features of the inventions and their advantages over the prior art, Figs. 3 - 8 illustrate several embodiments of the moving surface, in accordance with different aspects of the present invention.

Figs. 4 & 5 illustrate, a particle collection arrangement 400, which utilizes a fluid moving film 402, in accordance with one aspect of the present invention.
Particle collection arrangement 400 includes a dispenser 404, which is arranged to distribute moving fluid film 402 in a continuous and even manner without impediments along a chamber wall 406. By way of example, this may be accomplished by adjusting the flow rate of the fluid moving film. For the most part, the flow rate of the fluid is determined by gravity, volume, and the type of fluid used.

Preferably, dispenser 404 is disposed above an active region 408, which is defined by an upper process area 410 and a lower process area 412. As moving fluid film 402 flows down chamber wall 406 (e.g., through the active area), it collects a plurality of non-volatile species 414 that are proximate to moving fluid film 402 and transports them to a collector 416 disposed below lower process area 412 of active region 408. Preferably, the flow rate of the moving fluid film is configured to be balanced with the amount of non-volatile species being produced during processing to substantially reduce the accumulation of deposits. It should be understood that the actual placement of the dispenser and collector may very according to the specific needs of each processing system.

Furthermore, collector 416 is coupled to a reservoir 418, which is arranged to hold the moving fluid film that is saturated with non-volatile species. Reservoir 418 may also be configured to include a filtering element that cleans and regenerates the saturated moving fluid so that fresh or clean fluid may be pumped to dispenser 404 by a pump 420.
Additionally, a filter 422 may be disposed between pump 420 and dispenser 404 to remove any additional particles (e.g., non-volatile species) found in the pumped fluid. Filters are well known to those skilled in the art and will not be discussed here for the sake of brevity.

Moreover, if a filtering element is not provided within the reservoir then the old fluid can be removed and additional new fluid may be introduced through the pump.

Preferably, the fluid is configured to be a non-volatile, low viscosity and low volatility fluid (e.g., low vapor pressures). Further, the fluid is preferably configured to be resistant to the reactive species used for processing (e.g., chemically inert). In one embodiment, the fluid moving surface is preferably formed from a high vacuum oil. By way of example, a silicone oil works well. Silicone oils are inexpensive and readily available commercially. It should be noted, however, that the fluid moving surface may be formed from any fluid that is non-volatile, substantially resistant to the reactive species present within the chamber, able to collect non-volatile species present within the chamber, and able to move continuously along the chamber surfaces without impediments. By way of a second example, fluorinated carbon based oils may also be used as the fluid moving surface.

Figs. 6 & 7 illustrate, a particle collection arrangement 600, which utilizes a flexible moving surface 602, in accordance with one aspect of the present invention. Particle collection arrangement 600 includes a motorized roller system 604, which is arranged to move flexible moving surface 602 through an active region 606 of a process chamber 608. Motorized roller system 604 includes a first system of rollers 610 that are disposed above active region 606, and a second system of rollers 614 that are disposed below active region 606. Both system of rollers are arranged to surround the periphery of process chamber 608.

As flexible moving surface 602 moves between first system of rollers 610 and second system of rollers 614, it collects a plurality of non-volatile species 620 that are proximate to flexible moving surface 602 and transports them out of active region 606 and typically out of process chamber 608. In one embodiment, the velocity of the flexible moving surface is configured to be balanced with the amount of non-volatile species being produced during processing to substantially reduce the accumulation of deposits that tend to form on the flexible moving surface. In another embodiment, the flexible moving surface is moved after a certain number of substrates have been processed.

Furthermore, it has been found that when flexible moving surface 602 moves around a corner, i.e., rollers 610, 614, a flex region 622 is created that tends to dislodge deposited particles from flexible moving surface 602. Therefore, rollers 610, 614 preferably provide flexible movable surface 602 with tension so that a substantially flat region 624 is produced in active region 606. As a result, particle contamination produce by dislodged particles are

substantially eliminated in the active area.

Moreover, the flexible surface is configured to have the same material qualities as mentioned with regards to the fluid moving surface. That is, the flexible surface should be formed from a flexible membrane that is substantially resistant to the reactive species present within the chamber and able to collect non-volatile species present within the chamber.

Particle collection arrangement 600 also includes a cleaning arrangement 650. Cleaning arrangement 650 is preferably disposed outside of process chamber 608 (e.g., non-active area) so that a saturated side 652 of flexible moving surface 602 can be cleaned while an unsaturated side 654 of flexible moving surface 602 can be used to collect non-volatile species 620. Cleaning arrangement 650 is preferably configured to regenerate saturated side 652 of flexible moving surface 602 by removing the collected non-volatile species that are deposited on the flexible moving surface during processing. Cleaning arrangement 650 may include, but is not limited to, applying chemicals that are configured to remove the deposits to the saturated side, polishing the saturated side with a polishing pad until the deposits are removed, scraping the saturated side with a blade that dislodges the deposits, and the like. Accordingly, the flexible moving surface may be reused after the collected non-volatile species are removed from the saturated side of the flexible moving surface.

Although, the process chamber is described as being substantially cylindrical with vertical chamber walls, it should be understood that the present invention is not limited by the size and/or shape of the process chamber. For example, the process chamber shape may be triangular, rectangular, hexagonal, octagonal, spherical, and the like or the chamber walls may be sloped. Furthermore, it should be understood that although the moving surface has been described as moving from the upper process area to the lower process area (e.g. vertically), the present invention is not limited by moving in a specific direction in the process chamber. By way of example, the moving surface may move from side to side (e.g., horizontally).

Fig. 8 illustrates a top view of a processing system 700, which includes a particle collection arrangement, in accordance with one aspect of the present invention. In this figure, the moving surface is produced in accordance with the teachings of the invention set forth above with regard to Figs. 6 & 7. However, the process chamber is rectangular having a moving surface that moves side to side (e.g., horizontally). Processing system 700 includes a chuck 702, a substrate 704 and a process chamber 706, which is defined substantially by a flexible moving surface 708. Flexible moving surface 708 is preferably moved around

process chamber 706 by a pair of motorized rollers 710 and a plurality of guides 712. Because of a seam 714, which is formed at the entrance and exit of the flexible moving surface, the particle collection arrangement is disposed inside a vacuum environment 716 in order to maintain the appropriate pressures for processing.

As can be seen from the foregoing, the present invention offers numerous advantages over the prior art. By way of example, the present invention provides a moving surface inside the chamber that is arranged to collect and remove non-volatile species from the process chamber. Correspondingly, the moving surface substantially reduces the accumulation of deposits along the side walls, and therefore particulate contamination is reduced. Further, the need for cleaning the chamber surfaces is eliminated, and therefore substrate throughput is increased. Further still, a constant chamber condition is obtained, rather than one that changes as a function of substrates processed. That is, the effect of the wall on the process is constant. Additionally, the present invention provides a moving surface that protects the chamber surfaces from both volatile and non-volatile species. Correspondingly, the material that the chamber surfaces is formed from may be configured in a variety of ways because the volatile species no longer contacts them, this may reduce costs associated with designing a surface that resists volatile species, as well as, increase the life of the wall. Moreover, the present invention describes a way of making a process chamber so that the wall is continuously refreshed, or perpetually clean. Further still, the present invention provides a way for removing harmful particulate from the process chamber without substantially altering the processing conditions, i.e., chamber pressure, gas chemistry, etc. Thus, increased productivity may be achieved.

Note that although the preferred embodiment contemplates a moving surface without a heating element, it is possible to employ the present invention along with a heating element to increase the control of the chamber surfaces. By way of example, the moving surface could be used along with a chamber heating system to further reduce the amount of particles that deposit on the moving surface.

While this invention has been described in terms of several preferred embodiments, there are alterations, permutations, and equivalents which fall within the scope of this invention. It should also be noted that there are many alternative ways of implementing the methods and apparatuses of the present invention. By way of example, a sloped chamber wall may be used in order to achieve a proper flow rate for the moving fluid film. It is therefore

intended that the following appended claims be interpreted as including all such alterations, permutations, and equivalents as fall within the true spirit and scope of the present invention.

**What is claimed is:**

1. A system for processing a substrate using a process gas, said substrate processing system forming volatile and non-volatile species during said processing, said substrate processing system comprising:

a process chamber within which said processing is performed, said process chamber being configured to enclose said substrate, said process chamber having a chamber surface proximate to said substrate; and

a chamber surface protection arrangement configured for shielding said surface from said non-volatile species formed during said processing, said chamber surface protection arrangement including:

an adsorbing film, said adsorbing film being disposed inside said process chamber and substantially adjacent to said chamber surface, said adsorbing film being configured to prevent said non-volatile species from contacting said chamber surface, and arranged to adsorb a substantial portion of said non-volatile species that contact said adsorbing film, said adsorbing film further being arranged for removing said adsorbed non-volatile species from said process chamber.

2. The substrate processing system of claim 1 wherein said adsorbing film is a moving adsorbing film that moves prior to, during, or subsequent to said processing, wherein the conditions of said processing are allowed to remain substantially unchanged when said adsorbing film is moving.

3. The substrate processing system of claim 1 wherein said adsorbing film is a fluid adsorbing film.

4. The substrate processing system of claim 3 wherein said fluid adsorbing film is a moving fluid adsorbing film that moves prior to, during, or subsequent to said processing, wherein the conditions of said processing are allowed to remain substantially unchanged when said adsorbing film is moving.

5. The substrate processing system of claim 4 wherein said moving fluid adsorbing film

moves continuously throughout said processing to remove said adsorbed non-volatile species from said process chamber during said processing.

6. The substrate processing system of claim 5 wherein said moving fluid adsorbing film is in contact with said chamber surface during said moving, wherein said moving fluid adsorbing film is allowed to flow along said chamber surface.

7. The substrate processing system of claim 5 wherein said chamber surface protection arrangement further includes:

a dispenser for dispensing said moving fluid adsorbing film at substantially a first end of said chamber surface; and

a collector for collecting said moving fluid adsorbing film at substantially a second end of said chamber surface.

8. The substrate processing system of claim 7 wherein when said moving fluid adsorbing film is dispensed by said dispenser said moving fluid adsorbing film is allowed to flow along said chamber surface of said process chamber.

9. The substrate processing system of claim 8 wherein said chamber wall protection arrangement further includes:

a pump for pumping an unadsorbed moving fluid adsorbing film to said dispenser.

10. The substrate processing system of claim 3 wherein said fluid adsorbing film is substantially resistant to said volatile species formed during said processing such that said fluid adsorbing film blocks said volatile species from passing through said adsorbing film to said chamber surface, and prevents said volatile species from adsorbing into said fluid adsorbing film.

11. The substrate processing system of claim 10 wherein said fluid adsorbing film is a low volatility and inert liquid.

12. The substrate processing system of claim 11 wherein said fluid adsorbing film is

silicone oil.

13. The substrate processing system of claim 1 wherein said adsorbing film is a flexible adsorbing film.

14. The substrate processing system of claim 13 wherein said flexible adsorbing film is a moving flexible adsorbing film that moves prior to, during, or subsequent to said processing, wherein the conditions of said processing are allowed to remain substantially unchanged when said moving solid adsorbing film is moving.

15. The substrate processing system of claim 14 wherein said chamber wall protection arrangement further includes:

a conveying system for moving said moving flexible adsorbing film from a first end of said chamber surface to a second end of said chamber surface.

16. The substrate processing system of claim 13 wherein said flexible adsorbing film is substantially resistant to said volatile species formed during said processing such that said flexible adsorbing film blocks said volatile species from passing through said adsorbing film to said chamber surface, and prevents said volatile species from adsorbing into said flexible adsorbing film.

17. The substrate processing system of claim 1 wherein said adsorbing film is configured to cover substantially all of said chamber surface.

18. The substrate processing system of claim 1 wherein said adsorbing film is a thin adsorbing film.

19. The substrate processing system of claim 1 wherein said chamber surface protection arrangement further includes:

a cleaning arrangement disposed outside of said process chamber, said cleaning arrangement being arranged to remove non-volatile species that were adsorbed on said adsorbing film during said processing.

20. The substrate processing system of claim 19 wherein said adsorbing film is reused after said non-volatile species are removed from said adsorbing film.

21. The substrate processing system of claim1 wherein said substrate processing system is a semiconductor processing reactor.

22. The substrate processing system of claim 1 wherein said substrate processing system is a plasma processing reactor.

23. The substrate processing system of claim 1 wherein said chamber surface substantially surrounds said substrate.

24. The substrate processing system of claim 1 wherein said process chamber is a substantially cylindrical process chamber.

25. The substrate processing system of claim 1 wherein said chamber surface is a chamber wall that encloses a substantial portion of said process chamber.

26. A reaction chamber for processing a substrate, comprising:

a process chamber having an active region within which said processing is performed on said substrate; and

a moving film disposed inside said process chamber and defining a portion of the inner periphery of said process chamber, said moving film being configured for refreshing itself by moving in and out of said active region.

27. A method for controlling the amount of deposits that accumulate along surfaces in a process chamber during processing of a substrate, comprising:

introducing a moving film inside an active area of said process chamber;

collecting a plurality of non-volatile species on said moving film; and

removing said moving film from said active area of said process chamber.

28. A particle collector for controlling the accumulation of deposits along surfaces inside a process chamber of a semiconductor processing reactor used for processing a substrate, comprising:

a process chamber having a first end and a second end; said process chamber being defined and enclosed by a chamber wall;

a fluid configured for flowing on said chamber wall, said fluid being configured to collect a plurality of non-volatile species formed during said processing when said fluid flows past said chamber wall;

a dispenser for dispensing said fluid at said first end of said process chamber;

a collector for collecting said fluid and said collected non-volatile species at said second end of said process chamber; and

a pump for pumping said fluid to said dispenser.

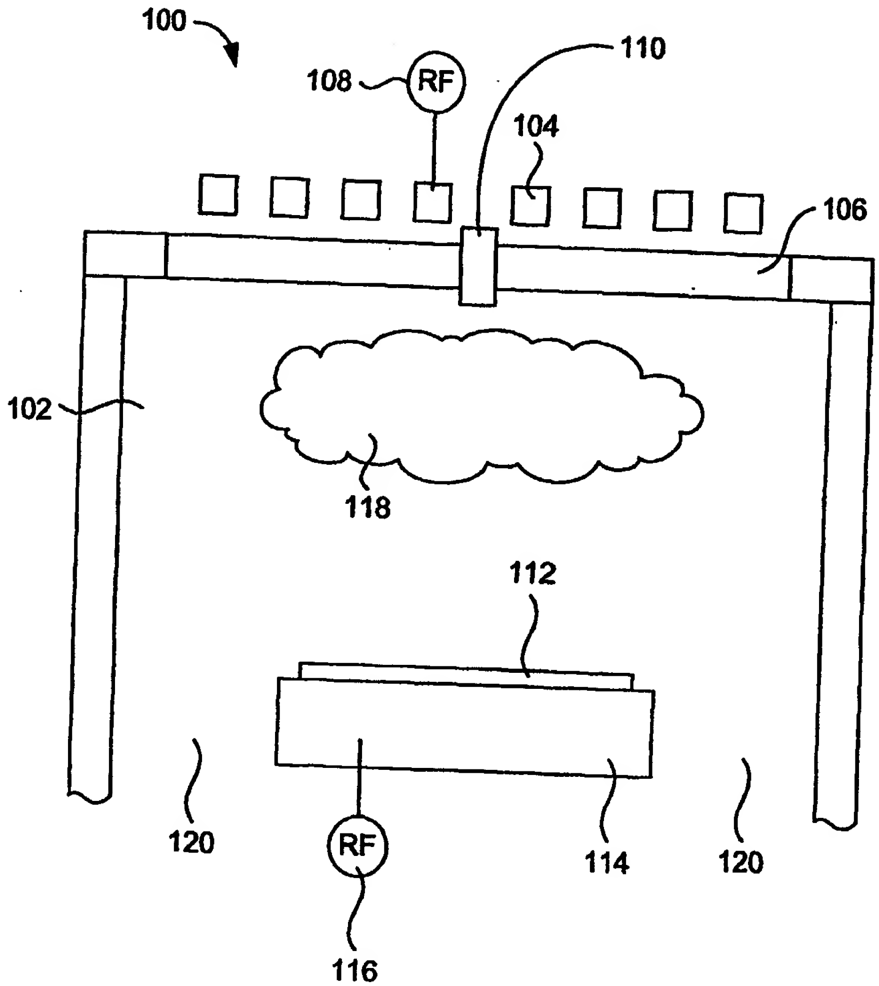
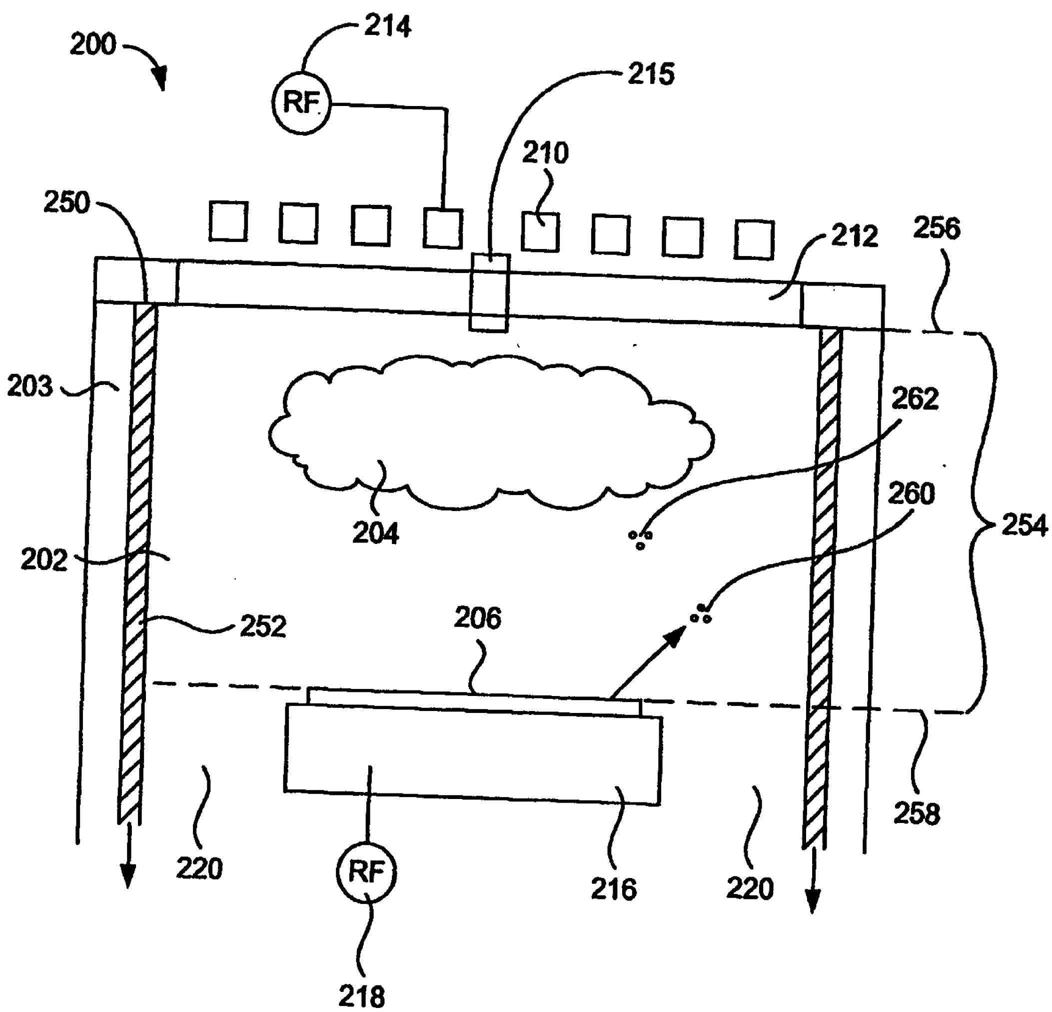



FIG. 1
(Prior Art)


200
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218

FIG. 2

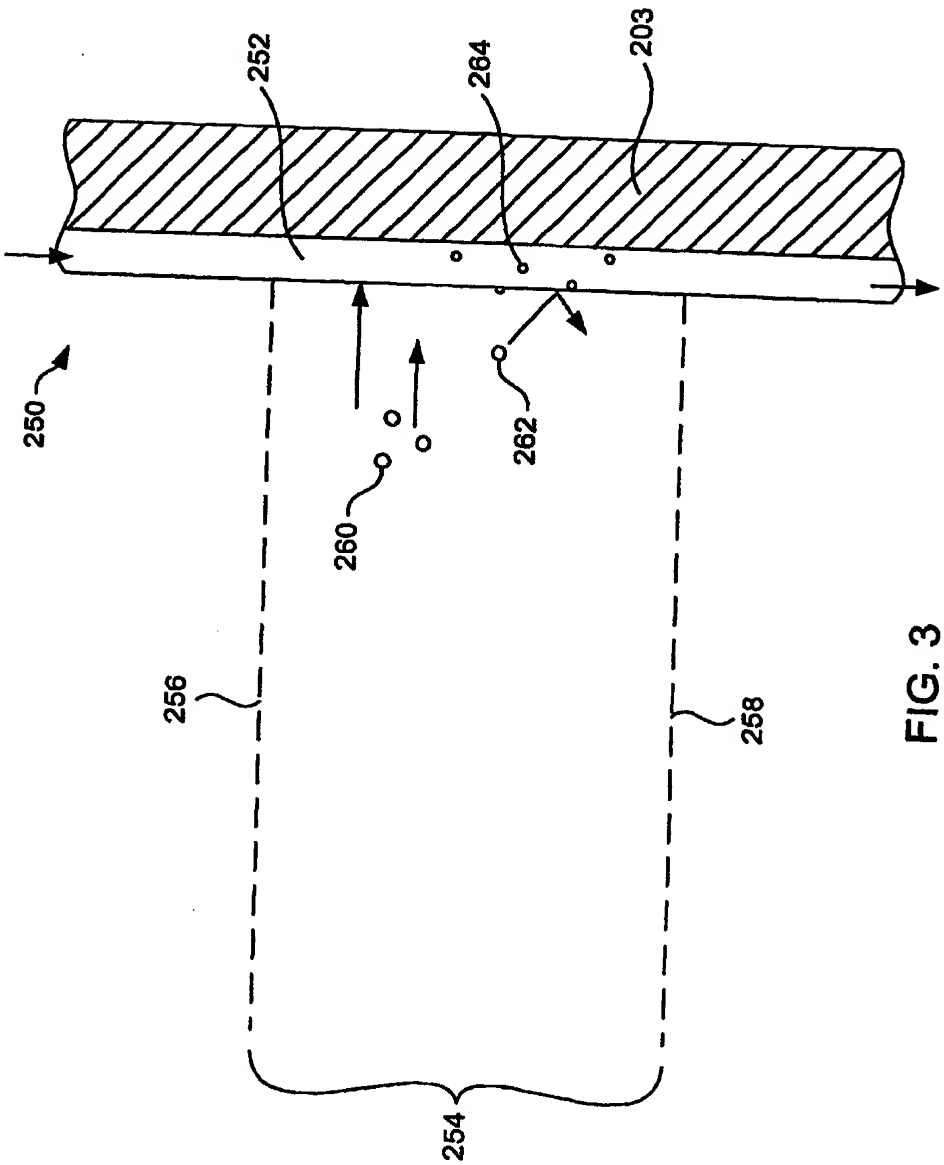


FIG. 3

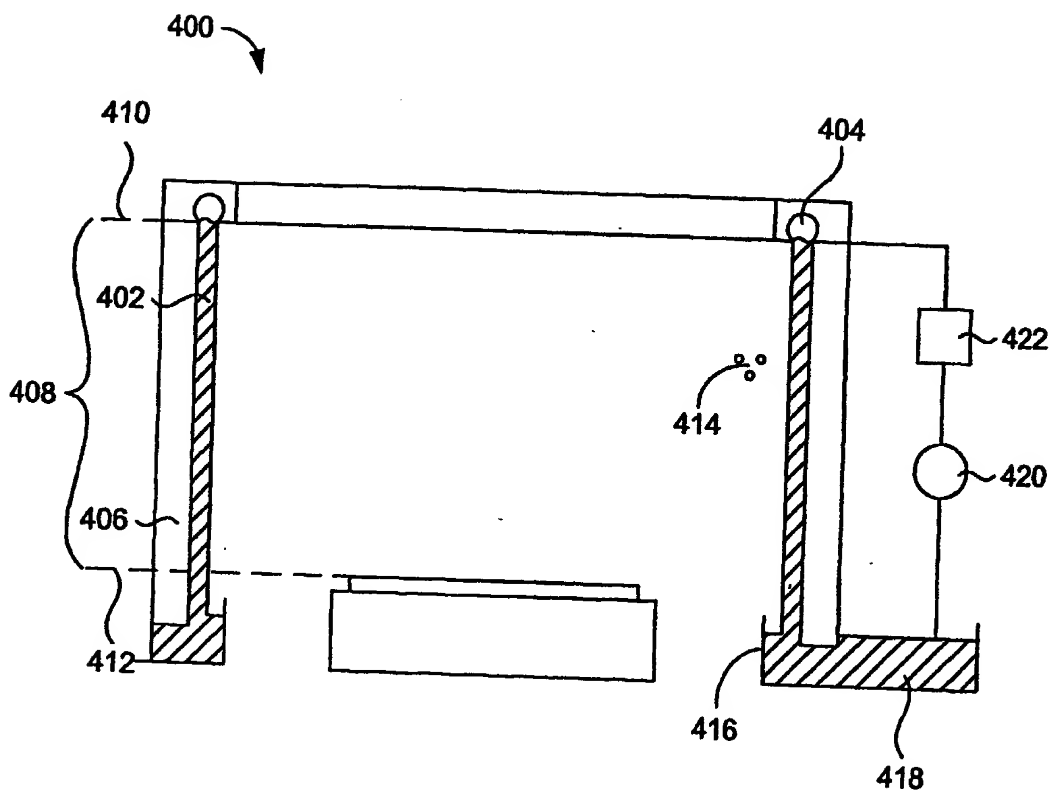


FIG. 4

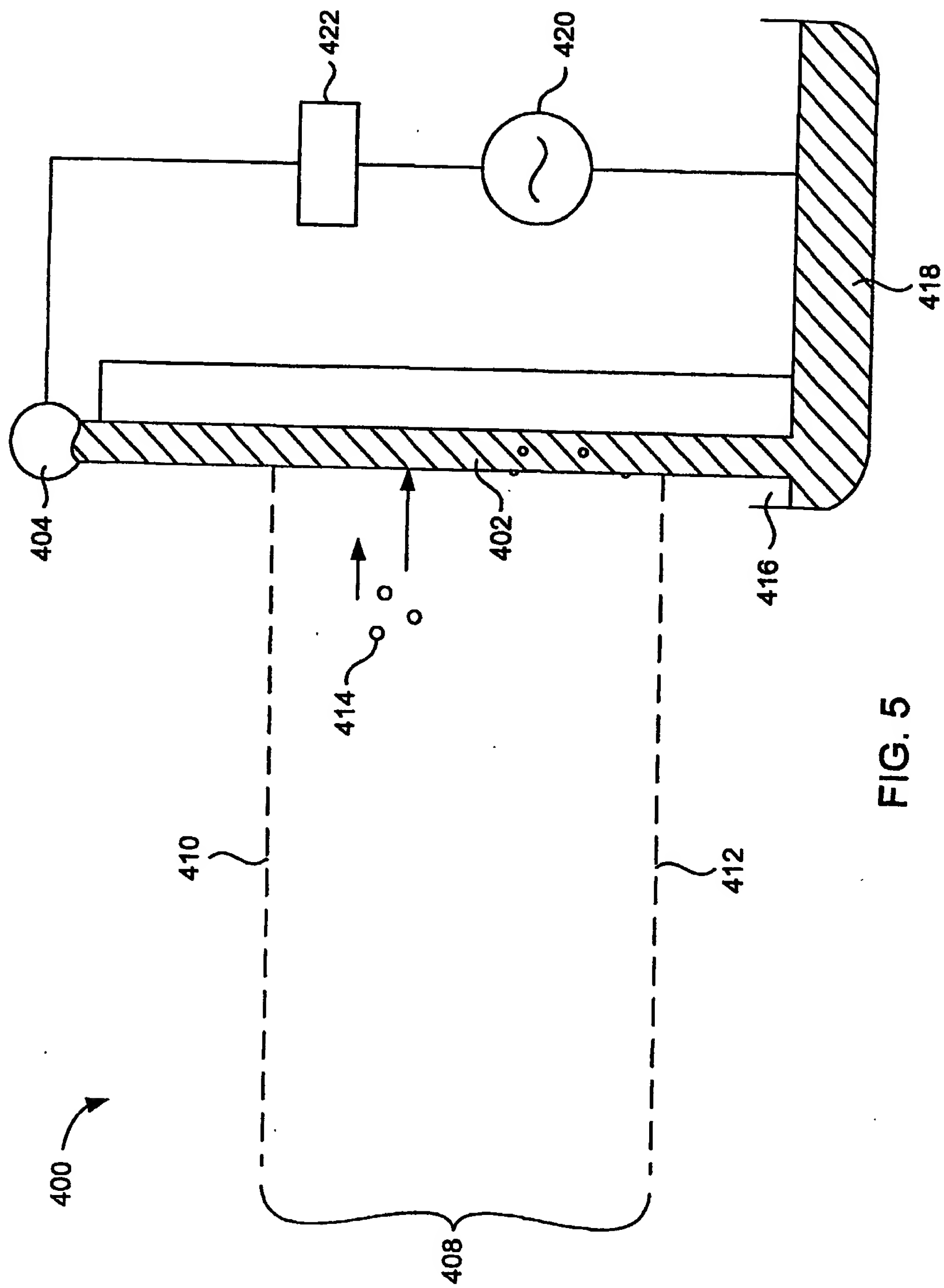


FIG. 5

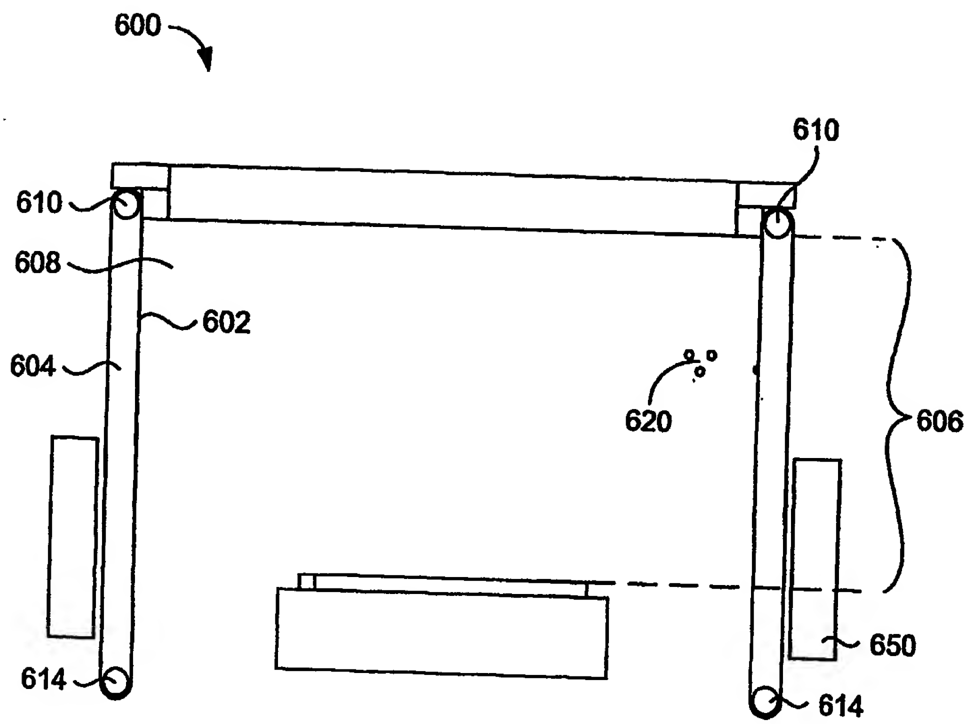


FIG. 6

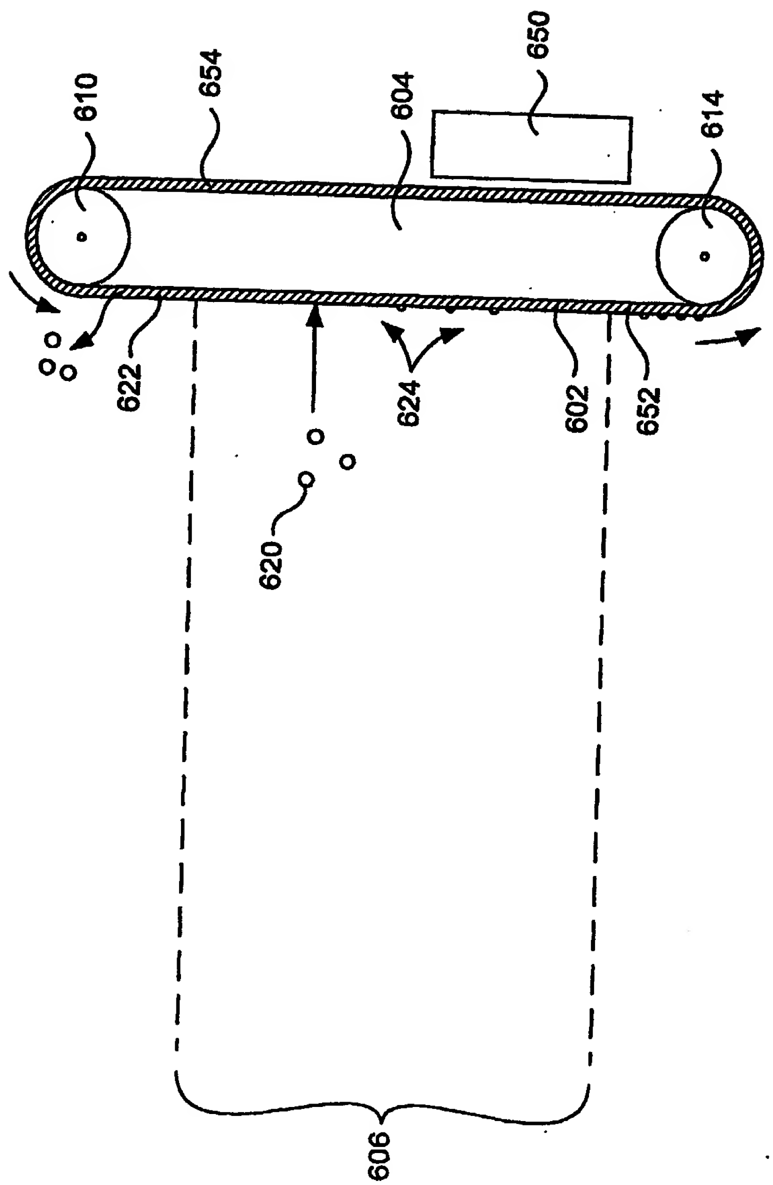


FIG. 7

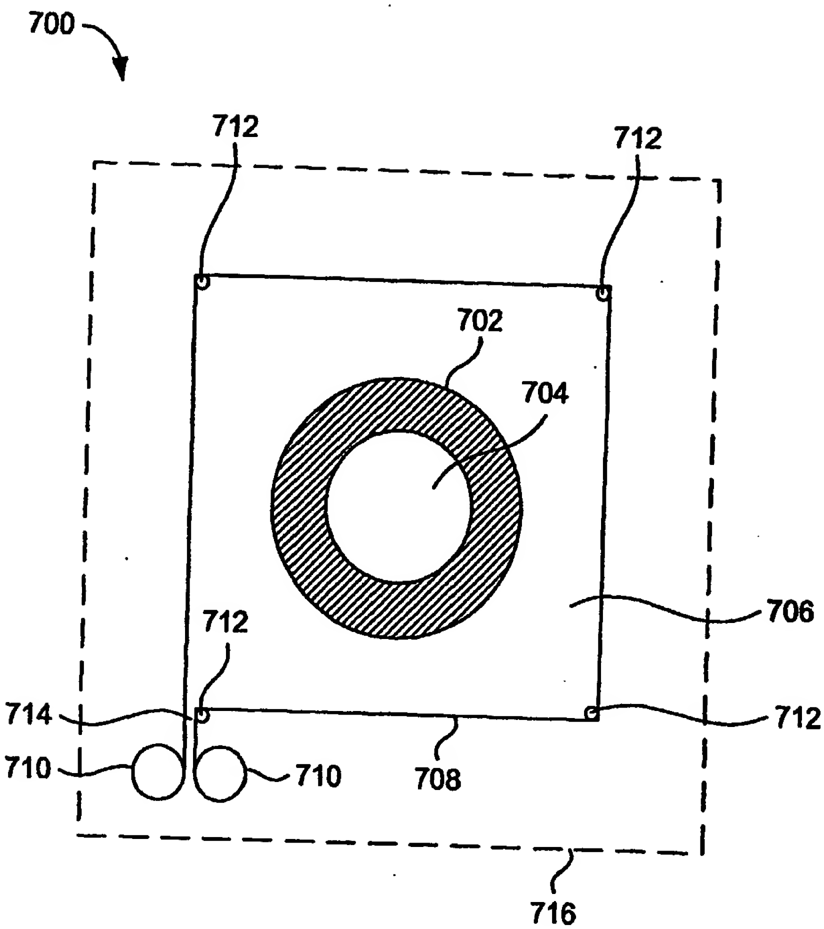


FIG. 8

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# INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/41001

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 C23C16/44 C23C14/56

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 5 622 565 A (YE YAN ET AL) 22 April 1997 (1997-04-22) | 1,3,17, 18, 21-23,25 |
| Y | column 3, line 62 -column 4, line 44; figure 1 | 4,5,7 |
| A | column 6, line 27-32 | 6,8-11, 16 |
| | column 7, line 22 -column 8, line 46 | |
| X | US 5 472 509 A (NOMURA HIROSHI) 5 December 1995 (1995-12-05) | 1,2, 13-15, 22-24, 26,27 |
| Y | column 1, line 55 -column 2, line 14; figure 3 | 4,5,7 |
| A | column 5, line 25-48<br>column 6, line 34-38 | 28 |
| | -/-- | |

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 13 February 2001 | 21/02/2001 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Castagné, C |

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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| US 5472509 | A | 05-12-1995 | NONE | | |
| JP 63246814 | A | 13-10-1988 | NONE | | |
| FR 1507784 | A | | NONE | | |
| US 4022928 | A | 10-05-1977 | NONE | | |